Productivity of Gum tartar in Southern Kordofan State. Sudan

By

Mustafa Kamil Mahmoud Fahmi

(B.Sc. Hon.)Forestry, University of Khartoum, 2003

A thesis submitted to the University of Khartoum in fulfillment of the requirements for the Degree of Master of Science in (Forestry)

Supervisor

Dr. Abdalla Mirghani Eltayeb

Department of Forest Management

Faculty of Forestry, University of Khartoum

April 2009

Dedication

To the soul of my beloved parents, to my dear brothers and sisters for their moral support, patience and priceless advice given to me during the visit to my study area.

Acknowledgement

I wish to express my sincerest thanks to my supervisor, Dr. Abdalla Mirghani El Tayeb for his excellent guidance and continual interest throughout, his creation of a free yet stimulating academic atmosphere. His never failing enthusiasm has encouraged me during this work. My understanding of the subject grew from the frequent discussions with him.

My sincere gratitude is extended to Dr. Abdelazim. Y. Abedlgadir for his friendly support and valuable suggestions to make a layout of my study work.

Special thanks are due to Dr. Amin. S. M. Ali who kindly has provided me with an opportunity to work in his study area and thoughtful comments on my manuscripts. He has that special talent of making corrections, respecting the work and talents of others. I am deeply grateful.

I am indebted to many other colleagues; Talaat D. Abdel Magid and Mr. Mamoun G. Musa for their excellent support, assistance and arrangement with other foresters in Southern Kordofan State during my successive field-work visits; also I am conscious of my debt to my colleagues Mr. El-Nour. A. M. El-Hag, Forest Director of Southern Kordofan State, Mr. Massaoud. M. Massaoud, Director-assistant of Rashad Circle, Osman A. Osman, Director-assistant of Al-faid Um Abdalla sawmilling Circle and Mohamed. A. El- Nour, inspector of El-abassia forest, who has collaborative, unlimited facilities and cordial hospitality during my visits to the study area. My thanks and appreciations go out to them.

I would like to send my warmest thanks to all Key-persons who took time to provide me with data and take us around for area selection during the field-work.

Finally I wish to express appreciation to all my colleagues and friends.

Declaration

I hereby declare that the work reported herein is a result of my own investigation, has not been accepted in substance for any degree and is not concurrently being submitted for any degree.

Candidate:
Mustafa Kamil Mahmoud Fahmi

Productivity of Gum tartar in Southern Kordofan State. Sudan

Abstract: The overall objective of the present research was to develop productivity equations of gum karaya (tartar gum) from *Sterculia* spp. as related to measurable growth parameters (height, diameter and crown height). The total area for this study was 75 hectare representing three locations each covering 25 hectare (500 m x 500 m). In each site, 50 sample plots were randomly chosen using random tables and GPS. The closest three trees to the centre of the each sample plot were selected for tapping by using an axe. The targeted trees for tapping were 116 trees from ALmazlagan area, 141 and 135 trees from bottom and top of Gabal Alahmar, respectively. Diameter at breast height (dbh), tree height (h) and crown height (ch) were measured for each tree and 8 gum collections were carried out for the sample trees starting from October 2006 to May 2007. Gum from each tree was collected, weighed and recorded for each selected sample tree. The data were analyzed using excel (spread sheet), SAS and JMP programs. Linear regression was used between measurable parameters with monthly gum picking and total gum production. The results for the three locations showed that there were significant differences between measurable parameters and monthly gum picking and crown height. In site Π; there was a significant difference in monthly gum picking and total gum production between diameter at breast height and average tree height. A total of 84 equations were developed for the three locations. The most important equations were relationships between height and diameter at breast height, crown height and diameter at breast height and crown height and height. The most important equations relating gum production and measurable parameters were relationships between total production and diameter at breast height, total production and crown height and total production and height

The study showed that the maximum gum production is on the mountain top followed by the mountain bottom with the least production in the plateau. The hottest months of the year (March, April and May) yielded the best gum quality and quantity.

انتاجية صمغ الترتر في ولاية جنوب كردفان. السودان

المستلخص: الهدف الرئيس من هذه الدراسة هو تطوير معادلات لإنتاجية صمغ الترتر(كاريا) من شجرة الترتر وعلاقتها بقياسات أجزاء الأشجار (الإرتفاع والقطر وارتفاع التاج).

كانت المساحة الكلية للدراسة 75 هكتاراً تمثل ثلاثة مواقع، كل موقع يغطي مساحة 25 هكتار(500 متر x 500 متر). أخذ في كل موقع 50 عينة أختيرت عشوائيا بأستخدام الجداول العشوائية وجهاز تحديد المواقع (GPS). أختيرت أقرب ثلاث شجرات لمركز العينة للطق بأستخدام الفأس. الأشجار المستهدفة للطق كانت 116 شجرة من منطقة المزلقان و141 و135 شجرة من أسفل وأعلي الجبل الأحمر علي التوالي. قيس كل من القطر عند مستوى الصدر، وارتفاع الشجرة، وارتفاع التاج وأجريت ثمانية عمليات جمع للصمغ ابتداءا من أكتوبر 2006 وحتى مايو2007. ولقد تم جمع ووزن وتسجيل إنتاح كل شجرة على حدة لكل موقع مختار، وبعد ذلك أدخلت البيانات في الحاسوب بأستعمال البرامج الحاسوبية Excel وتم التحليل الإحصائي عن طريق Excel و SAS و JMP وأستخدم تحليل الإنحدار الخطي لإيجاد العلاقات بين أجزاء الأشجار والجمع الشهري والإنتاج الكلي للصمغ.

أظهرت النتائج أن هنالك إختلافات معنوية بين عناصر الأشجار مع بعضها البعض و الجمع الشهري من الصمغ وارتفاع التاج في المواقع الثلاثة، أما في الجبل الأحمر فكانت الإختلافات معنوية في الجمع الشهري من الصمغ والإنتاج الكلي من جهة والقطر عند مستوى الصدر ومتوسط ارتفارع الأشجار من جهة إخرى.

طورت 84 معادلة في المواقع الثلاثة، وتعد العلاقات بين ارتفاع الأشجار والقطر عند مستوى الصدر وارتفاع التاج والقطر وأرتفاع التاج وأرتفاع الاشجار من أهم المعادلات، كذلك من أهم المعادلات بالنسبة لإنتاج الصمغ والعناصر التي قيست في الأشجار هي العلاقات بين الإنتاج الكلي والقطر عند مستوى الصدروالأنتاج الكلي وارتفاع التاج والإنتاج الكلي والارتفاع

أظهرت الدراسة أن أعلى إنتاج لصمغ الترتر هو في أعلي الجبل يليه سفح الجبل و أقل إنتاج في الهضبة (إنحدار خفيف)، بينت الدراسة أن الشهور الحارة من السنة (مارس وابريل ومايو) أعطت أفضل انتاجية من صمغ الترترمن حيث النوعية والكمية.

Table of contents

List of Tables

List of Figures

ABBREVIATIONS

ADI	Acceptable Daily Intake
CH	Crown Height
Cm	Centimeter
DBH	Diameter at Breast Height
FAO	Food and Agriculture Organization
FNC	Forests National Corporation
GCC	Girijan Cooperative Corporation
GIS	Geographical Information System
GPS	Geographical Position System
GRAS	Generally Recognized As Safe
Gm	Gram
H	Height
Ha	Hectare
M	Meter
MDGs	Millennium Development Goals
NTFPs	Non Timber Forest Products
NWFPs	Non Wood Forest Products
TY	Total Yield
Y	Yield

CHAPTER ONE
INTRODUCTION

1.1 Background

Forests in the Sudan extend across several agro-ecological zones, which imply the existence of a variety of fauna and flora species that contribute directly or indirectly to the sustainable livelihood of local communities. An accumulated local knowledge with respect to the use of trees and forests for provision of food and other non-wood materials has been recognized.

Forests, as a natural resource, have a significant role to play in assuring present and future food security by improving both the economic and physical well-being of rural people (Sanjak, 2000). Forests constitute about 90% of terrestrial biodiversity and contribute to the livelihoods of over 1.2 billion people. The majority of these people are poor and depend significantly on forests for their livelihood (World Bank, 2002). The role of the forests can be felt directly in the production of Non-Wood Forest Products (NWFPs) that provide substantial cash income and edible fruits to the rural people. Important tree species from the dry savannah that produce NWFPs include *Sclerocarya* sp, *Tamarindus indica*, *Ziziphus* sp, *Sterculia setigera*, *Sterculia africana*, *Adansonia digitata*, *Boswellia papyrifera*, *and Hyphaene thebaica*….etc. The term Non-Wood Forest Product was coined by Debeer and McDermott (1989), in an attempt to raise the awareness towards the importance of forests other than commercial logging.

The contribution of NWFPs to livelihood is not reflected in the formal national economy, and, therefore often not appreciated by policy-makers (Sanjak, 2000). A main driver for research in the area of NWFPs has been to raise the awareness towards alternative values of forests in an attempt to promote the sustainable use and conservation of forest ecosystems. Equally important has been the realisation that forests are a critically main resource for the maintenance of rural livelihoods. Commercial deforestation for timber does very little in providing livelihood opportunities to the forest dwelling communities, and can result in decreased livelihood opportunities in the long-run (Kumar and Saxena, 2002).

The contribution of NWFPs in livelihood support has been underestimated. Of particular importance is their contribution to rural communities in terms of food and nutritional requirement through direct consumption of food materials obtained from the forests and tree products such as edible fruits, in addition to the use of trees in folk medicine, mushrooms and honey (Dovie, 2003) or through indirect support to household food security. Such supports come in different forms like provision of materials for business such as firewood, charcoal, gums, resins, etc (FAO, 1991; FAO, 1995). Figure 1.1 reflects the main source of income for households in some areas in Southern Kordofan State and their contribution to poverty reduction.

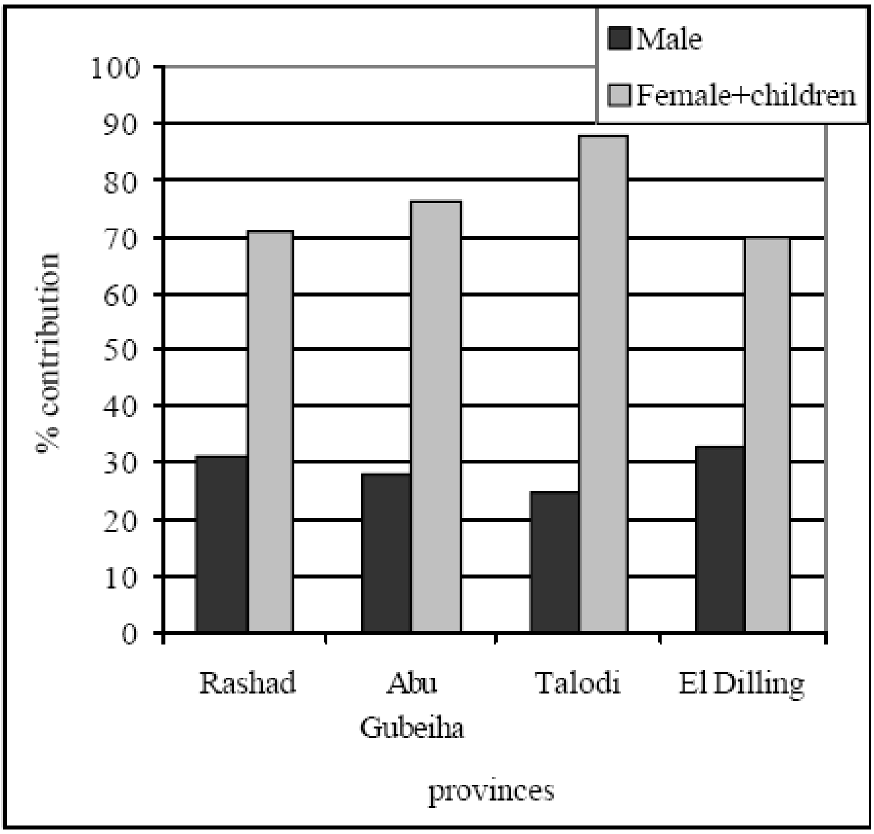

Fig. 1.1 Contribution of NTFPs to household income in Southern Kordofan State (source: Bashir and Jens, 2004)

According to the World Health Organization 2002, 2 billion people rely on traditional medicine from forests for their health. Maintenance and improvement of ecology, is also achieved by the presence of forests and tree products. Good soil conservation and fertility with improved conditions of rainfall availability is partly a function of forests and tree products with direct contribution to the achievement of the Millennium Development Goals (MDGs) particularly towards poverty alleviation (Weerawardane, 2003)

The most important role played by NWFPs in the Sudanese rural areas (especially for the poor) is the provision of food and job opportunities outside the agricultural season, for gums and resins (Sanjak, 2000). The natural forests from mid 1960s onwards showed a decline in the forest growing stock that has continued at an increasing rate as a result of land-use changes and mismanagement (FAO/FNC, 1998). Also, the consumption of forest products has increased to almost four times the annual allowable cut (FAO/FNC, 1998). The rate of deforestation and the forest depletion is almost 29 times the rate of present reforestation (Gaafar, 2005). Consequently, the forest-adjacent to communities, which depend on wood and non-wood forest products and on crop cultivation, have been negatively affected. Proper forest management planning in the Sudan has been limited to very few areas, mainly plantations, which constitute less than 2% of the total reserved area. The remaining natural forests have been left unmanaged with far reaching consequences on vegetation and soil degradation (Gaafar and Alasha, 1997).

1.2 Problem statement

Sterculia setigera is one of the species that an important for livelihood in rural communities and can produce gum tartar for local consumption and commercial production at the local and international levels. However, the literature on gum tartar in the Sudan very few studies were conducted in this filed and still fragmented. Gum karaya can be an important export commodity if properly managed. Studies of NWFPs used for livelihoods are in particular poorly researched and documented in Sudan. The effect of the tree growth parameters on the yield of gum karaya is almost ignored in almost all the researches that dealt with NWFPs. Hence, worth mentioning that, gum karaya started to draw the international attention due to its various uses Therefore, this study attempts to focus on this subject.

1.3 Objectives

The broad objective of this research is to develop an equation that describes productivity of gum karaya from *Sterculia spp* relying on measurable growth parameters (height, diameter, crown and density). Specific objectives are:

- To investigate the relationship between the different growth parameters and gum productivity of *Sterculia spp*.
- To develop an equation based on the relationships between growth parameters and the gum yield of *Sterculia spp.*
- To assess the natural regeneration of the species in the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1. General

In the Sudan, The species which are commercially tapped are *Acacia senegal* (Hashab), *Acacia seyal* (Talh) and *Boswellia papyrifera* (Gafal or Tarag Tarag or Rut-Rut) and ninety percent of the gum exported from Sudan is hashab (Ross, 1979).

Sudan accounts for nearly 80% of the world production of gum arabic. The total production and its distribution between different producing areas have undergone changes (There is a noticeable declination in Kordofan, Darfur and Eastern States while the Central State is promising). The Gum Arabic Company is responsible as monopolist tree producing. However, this is not the actual production. Some of the production is smuggled outside the country especially to Chad and Ethiopia due to the high international prices compared with what is paid of the local merchants, hence smuggling is extremely profitable.

Another type of gum, is talh gum, which is produced from *Acacia seyal*. It is closely linked to the production of hashab gum (*Acacia senegal*). When production of hashab gum is high neither the producer nor the Gum Arabic Company are interested in talh gum. When there is a short fall in hashab gum production, farmers collect talh gum to substitute the losses in hashab gum, although talh gum prices are lower (El Amin, 1973).

2.2. Geographical Distribution of genus *Sterculia*

The *Sterculia* or karaya (tartar) tree is a native of dry deciduous forests in tropical climates. The genus *Sterculia* comprises about 100 species of which approximately 25 species are said to occur in South Africa's tropical forests. *Sterculia* is found in tropical Himalayas (Anderson *et al.,* 1982). It is also found across the whole of the Sahel and further south towards Angola, usually on hilly or fallow ground. In Sudan *Sterculia* species are fairly widespread in the high rainfall savanna area, which covers about 11% of the country where rainfall starts from 500 to more than 1000 mm (Andrews, 1952). It is growing on hilly ground with tall grass in the Blue Nile, Kassala, Darfur (J. Marra), Kordofan, Red Sea States and common in the Southern Sudan (El Amin, 1990).

2.2.1. Species of *Sterculia* and their distribution

2.2.1.1 *Sterculia* species in India

Most commercial gum karaya is obtained from *Sterculia urens*, the only tree tapped for gum harvesting, belongs to the family Sterculiaceae, a large bushy deciduous tree that can grow up to 15 m high. It is found on the dry, rocky hills and Deccan plateaus of central and northern India and throughout the Eastern and Western Ghats of India (Chopra *et. al.,* 1956). Other species occuring in India, are. *S. foetida, S. populiana,* and *S. willosa* (Coppen, 1995).

India forests are a potential source for large numbers of Non Timber Forest Products NTFPs and therefore, support livelihoods of those living in and around forest areas. In Andhra Pradesh, some 10,000 tribal families living in 23 Districts within three regions, Coastal Andhra, Telangana and Rayalaseema, rely on the collection of gum karaya and other NTFPs for their livelihood (Malhotra *et al*., 1991). Andhra Pradesh State is one of the major producers of gum karaya in India. Other NTFPs include gums and resins, nuts, seeds, roots, tubers, flowers, fruits, leaves, and medicinal herbs. Are only available only for short periods 1-2 months while gum karaya, can be harvested round the year, which provides a steady source of income to the dependent gum collectors. Figure 2.1 shows the shape of *Sterculia urens* in Andhra Pradesh. India.

Fig. 2.1 The **shape of** *Sterculia urens* in Andhra Pradesh, India.

(Source: http:// www.Malvaceae/Genera/Sterculia/gallerg.html.)

Date of visited website: October, 2008)_

2.2.1.2 *Sterculia Spp.* in Sudan

Sterculia setigera (Del.) and *Sterculia Africana* which belongs to the family Sterculiaceae. is found in the Sudan-Sahel and in the Sudan-Guinea zone. It is also found In Senegal, Togo, and Somalia, East Africa and Angola (Maydell, 1990). In Sudan *Sterculia setigera* known as Tartar and Fidir.

2.3. Description of *Sterculia* (Del.)

Sterculia is a deciduous tree up to 16 m high, the common trees are leafless in the cold season; young leaves sprout in the hot season. Bole with small buttress at the base. Bark grey-purple, flaking in oblong scales which leave pale grey or greenish-yellow patches on falling. Slash red with paler streaks, exuding white gum and watery sap. Young branches velvety, older branches rough rugose with leaf scars. Leaves suborbicular or ovate, 3-5- lobed, 8-20 cm broad, tomentose on both sides but densely so beneath, sometimes velvety; petioles 6-13 cm long, grey tomentose. Inflorescence 4-9 erect, tomentose cymes produced on leafy or leafless twigs; sepals green outside, 1.2- 1.3 cm long; petals absent. Fruit grey-green or brown, usually 4 together, sessile, oblong, beaked, 5-7 * 3.8 -5 cm, velvety inside with numerous pungent red brown bristles on the outside; seeds numerous, purplish-black with small yellow-brown fleshy aril at base. Flowers Dec – March; fruits April- May (El Amin, 1990). Figures 2.2 and 2.3 show the shapes of the two species of *Sterculia* found in the Sudan, namely *Sterculia setigera* and *Sterculia africana*.

 

Fig. 2.2. *Sterculia setigera* Fig. 2.3. *Sterculia africana*

(Source: present study September, 2006)

2.3.1 Tree requirements

The tree species requires rainfall of more than 500 mm; it grows well on poor soils and on hilly/stony sites; altitude between 1,000-1,700 m, temperatures not known although it occurs naturally in areas with temperatures of between about 10°-40°C.

2.3.2 Natural regeneration of *Sterculia*

New seeds germinate reasonably well, with about 30% of it coming up. The seed takes approximately 2 weeks to germinate and can be planted in full sunlight. After this time, growth in the nursery is slow and seedlings are ready for planting out after 4 months. (Thirakul, 1984, and El Amin, 1990). Grazing animals and rodents are the main factors causing limitation of natural regeneration of the tree. Figure 2.4 demonstrates the natural regeneration of *Sterculia setigera* growing in Gabal Al hamer locality, Southern Kordofan State, Sudan.

Fig. 2.4. Natural regeneration of *S. setigera* **in Gabal Al hamer (2007)**

(Source: present study September, 2006)

2.4. Gum karaya production

2.4.1. Product description

Gum Karaya, sometimes known as *Sterculia* gum, is the dried exudation of the *Sterculia* tree, the species are normally found as native tree in many worldwide areas (Anderson *et al*., 1982; Coppen, 1995). Gum karaya also known as Indian tragacanth which is obtained almost exclusively from Indian plantations of *Sterculia urens* and smaller plantations of *S. villosa*. In Sudan, and elsewhere in Africa, gum karaya can be obtained from *S. setigera* (Coppen, 1995). Exudates from these three species are very similar in chemical composition and physico-chemical characteristics (Goldstein and Alter, 1973). Accordingly, in terms of current legal definitions of identity and trade specifications, exudates from any *Sterculia*, or admixtures, can be offered for sale.

2.4.2. Methods of tapping in India

There is some natural exudation of karaya but most gum is produced by tapping. Descriptions of the tapping vary from one place to another. Gum karaya tapping requires a specialized skill and knowledge in order to access the best quality, while minimizing damage to the tree, but all entail removal of sections of bark from the trunk of the tree. Guidance rules have been laid down by the Forest Research Institute, Dehra Dun, in India, but in practice the rules are not adhered to and the dimensions of the blaze are often exceeded. Tapping which involves deep and wide wounds to the tree to maximize gum yields is damaging the tree. Previously, the tribals used to cut multiple blazes on a single tree to obtain maximum gum. Ultimately leading to over exploitation of the tree. They collected more gum per tree approximately 100-150 grams per tree per blaze, but the quality was poor and the gum trees were often severely damaged, and this led to a ban on tapping by one Indian Forestry Department in the 1980s (Nair *el al.,* 1995). In the early 1990s, the tribals used axes to produce the gum. Both men and women are involved in the pre-harvesting of gum karaya. Men conduct most of the gum blazing while women manage processing drying, grading and storage. The gum mixed with bark and other foreign matter when it was sold in the place shading. There was no knowledge of how the gum could be collected, cleaned, sorted and graded. Girijan Cooperative Corporation (GCC) was unable to dispose of those stocks which resulted in a backlog of over 1200 tons of gum, stored in the GCC go-downs for want of marketing.

In India, tapping should be confined to trees with a minimum girth of 90 cm(dbh=28.7cm) and the initial size of the blaze should be limited to 15 cm long, 10 cm wide and 0.5 cm deep. Sixteen successive visits should be made to the tree at two-weeks intervals, removing a further two cm high section of bark above the previous one at each visit, and leading to a maximum depth of the blaze of 2.5-3.0 cm. an additional blaze can be worked for every 50 cm girth increment above 90 cm, provided that sufficient space is left between adjacent blazes. By staggering the position of each new season's blazes it is possible to leave a rest period of six years before returning to a previous one, by which time the scar should have healed. Tapping is best done during the hot season to maximize yields (Howes, 1949; Goldstein and Alter, 1973; Coppen, 1995). Figure 2.5 shows a tapped *S.urens* tree in Andhra Pradesh, India.

Fig. 2.5 A **tapped tree (*S.urens*) in Andhra Pradesh, India.**

(Source: http*ll*:www. krystal- colloids.com. visited website October, 2008)

2.4.3. Gum karaya exudation

Gum karaya exudation begins immediately after wounding the *Sterculia* tree and is particularly extensive during the first days. The exudate is allowed to solidify on the tree and is then removed as large, irregular tears (Verma, 1988). In India, the world's biggest producer of gum karaya, the best quality gum is collected from April to June, before the monsoon season, as the temperature increases. Collection may be repeated in September, although in this period gum may be less viscous and darker, due to the presence of higher amounts of foreign matter. Commercial Indian gum karaya is available in four different grades, hand-picked selected, superior no.1 and no. 2, fair average quality, and siftings (FAO, 1995). The higher grades contain less foreign matter and have a lighter color.

In Senegal and Sudan the African producers of gum karaya, harvesting is done from September to June. After collection, the gum is manually or mechanically cleaned and sorted. Figure 2.6 displays gum karaya exudation from *Sterculia setigera* in Gabal Al hamer area, Southern Kordofan State, during 2007.

Fig. 2.6 Gum karaya exudation from *Sterculia setigera* in Gabal Al hamer,.

(Source: present study May, 2007).

2.4.4. Collection and marketing

Villagers living in the vicinity of forests are engaged for collection of the gum. A common method is to make blazes on the tree trunk with some sharp edged tool. The gum begins to exude as soon as the blaze is made and exudation continues for many days. Exudation is better in hot months from March to May/June. No tapping is done in rainy season. The yield of gum varies from 1 to 5 Kg per tree per season, depending on many factors (Verma, 1988). Due to indiscriminate and unscientific tapping the trees often die. Gum collected by the villagers is usually sold by auction to government agencies in each of the producing States, through the agents appointed by the trading corporation at rates fixed according to quality of gum who then undertake final cleaning, drying, grading and packing of the gum in gunny bags and transport it to towns. Freshly collected gum often contains moisture and sticks to the bags which bring down its quality. The gum karaya often contains many impurities like tree bark, wood, fibre and a small amount of sand. Regulatory authorities set maximum specifications of 3% of bark and foreign organic matter content. The specifications also indicate a maximum of 1% of acid-insoluble ash (Goldstein and Alter, 1973).

2.4.5. Grading of Gum karaya

Grading of gum karaya as stated by (BIS, 1988). At the grading centre the big lumps are broken into small pieces of about 1 to 3 cm in diameter. The broken pieces are then graded manually in four different grades, which are registered with the Indian Agmark Organization, and which are based mainly on criteria of viscosity, colour and freedom from external bark, sand etc. Grade one often is whitest in colour , bark and foreign organic matter are less than 0.5% and viscosity at 1% >1000 cps, while grade four is brown in colour with impurities more than 3.0% and viscosity at 1% >300 cps (Meer, 1980). The graded gum is packed in heavy duty bags of about 80 Kg each. Sometimes the gum is powdered and packed in 5 to 6 Kg kraft paper bags or 75 to 100 Kg fibre drums (Goldstein and Alter, 1973).

2.5. Production and marketing of Gum karaya

World production of gum karaya is currently about 5,500 tonnes per annum with a declining trend. India is the only main regular producer, overwhelmingly dominating international trade in the gum karaya. During the period from 1960s until the mid-1980s, the annual export of India averaged 4,000-6,000 tonnes (FAO, 1995). Average exports for the period 1977/78-1982/83 were approximately 5700 tonnes/year (Robbins, 1988). Data of the years 1987/88-1993/94, show that the six year annual average for this period is less than 1,300 tonnes, a sharp decline during the same period a decade earlier (Prior to 1990s) when trades offered lower prices for gum karaya, procurement prices also declined and production as export dropped. This was due to substandard quality of gum karaya, as supplied by various agencies. The Untied States, France and the Untied Kingdom are the biggest markets for karaya (ANON., 1987). The demand in the Untied States has fallen to such a degree that France is now the main importing country (Robbins, 1988). Approximate annual consumption average over the whole of the recent period are; France 400 tonnes, Untied States 360 tonnes, the Untied Kingdom 210 tonnes and Japan 110 tonnes. Germany, Italy, Belgium and the Netherlands have also imported directly from India in most years (averaging 130 tonnes/year too all of them); so Europe as a whole import almost is twice the size of the American market. Total gum production was about three times that amount, since most Indian gum was and probably still is consumed domestically. At the end of the 1980s, gum supply collapsed, reaching about 570 t in 1991-1992. The reason for that dramatic decrease was the switch to a government-controlled market. Initially, the local industry was organized through private merchants, but in the 1980s the entire gum market from collection to export came under government control (Imeson, 1992). Initially, the government introduced a conservation policy; where tapping restricted and replanting was initiated to secure the gum for the future. Recently government controls were released and accordingly export has increased again, but is still gum karaya below the production level of the mid-1980s. It seem that it is not easier for India to regain its original dominance in the gum karaya market, since amounts exported by African countries is increasing at almost rate.

In Africa, Senegal is the biggest producer and exports annually about 1,000 t. Sudan exports only small amounts of gum karaya, although there is numerous *Sterculia* trees. Sudan, therefore, has the potential to become an important supplier in the future, if the same efforts provided for gum karaya as for gum Arabic (Verbeken, 2003).

2.6. Gum karaya Uses

Only 10% of produced gum karaya is used as a food additive; the remainder goes into pharmaceutical products (Anderson, 1993). The pharmaceutical applications of gum karaya include medical colostomy bag fixings, dental fixatives and bulk laxatives. Colostomy bag fixings are the most common use of gum karaya, in which the gum's qualities are difficult to equal. Its use in, dental fixatives started declining when research showed that habitual use of acidic gum karaya had an adverse effect any remaining natural teeth (Anderson, 1993). Its principal food applications include ice creams, ice pops, sherbets and salad dressings. Gum karaya is classified as "Generally Recognised as Safe" (GRAS) within the USA for use up to specified upper limits and in specified food products and as Acceptable Daily Intake (ADI) not specified by the joint FAO/ WHO expert committee on food additives (JECFA). At present scientific committee for food of the EEC, in contrast, restricts the human intake of gum karaya (E416) to an upper limit of 12.5 mg per body weight per day, but it has never been permitted in Germany for its food applications (Anderson, 1993). Commercially it was sometimes used as inferior substitute for tragacanth, and this led to its alternative name of Indian Tragacanth. (Tragacanth gum is the second most important Indian commercial gum, dried exudate produce by tapping of the tap roots and branches of certain shrubby species of *Astragalus*; it's similar to gum karaya in respect of uses (Anderson, 1988).

As perception in rural communities, trees have various medicinal uses. The extracts of the bark are used for jaundice and belharsia treatments, leaves and bark for cough, diarrhea, fever, leprosy and syphilis. The fibers are used in ropes and mats making (Maydell, 1990). Due to its acid stability, high viscosity, and suspension properties, gum karaya is well suited for stabilizing low pH emulsions, such as sauces and dressings (Partyka, 1963). Gum levels of 0.6-1.0% are used to obtain the desired texture, color, and suspension, but during processing care must be taken regarding the heat-and shear-sensitivity of the gum. In French dressing, gum karaya functions as a stabilizer, increasing the viscosity of the aqueous phase of the oil-in-water emulsion (Dziezak, 1991). In cheese spreads (Coppen, 1995), gum karaya is used as a binder to provide texture and spreadability and to prevent water separation. In salads, the gum acts as a stabilizer and prevents the weeping of the water from the oil-in-water emulsion (Beach, 1969). It is also incorporated in aerated daily desserts and whipped cream, where it acts as a foam stabilizer. Gum karaya significantly reduces the bioavailability of calcium in milk-based foods, as demonstrated by (Kelly, and Potter, 1990). In frozen desserts, such as sorbet, sherbet, and ice lollies, gum karaya is used in concentrations typically varying between 0.2% and 4% (Weiping, 2000). It controls the formation of ice crystals, preventing them from growing tool large, prevents the migration of free water, and reduces the suck-out of color and flavor during consumption. It is also found in ice cream, together with locust bean gum.

In sausages, gum karaya is used in concentrations ranging from 0.75% to 3% and performs several functions (Allen and McCaleb, 1938). It acts as an adhesive between meat particles and as a water-binder during preparation and storage. During smoking and cooking, the gum seals the appropriate sensorial characteristics to the product, such as a smooth texture, mouthfeel, body, and appearance (Allen and McCaleb, 1938).

2.6.1 Non-food applications

Most gum karaya is consumed in the pharmaceutical industry, where it is used in diverse applications. It functions as an adhesive in leakproof sealing rings for post-surgical drainage pouches or ostomy bags (Carpenter, 1979 Marsan, 1967, Sanderson, 1996). Coarse gum particles are very effective as bulk laxative as they absorb water and swell to 60-100 times their original volume. They are neither digested nor absorbed in the human ingestion channel. Powdered gum karaya is widely applied on dental plates as an adhesive (Steinhardt and Goldwater, 1962). When brought in contact with the moist surfaces of the mouth, the gum does not dissolve but swells and provides a more comfortable and tighter fit of the plate. Furthermore, it is broad to be very resistant to bacterial and enzymatic degradation. In tampons, gum coatings form a gelatinous medium in contact with body fluids, preventing irritation of the mucous membranes and facilitating removal after use (Boiteau, and Blondeel, 1981).

Deacetylated gum karaya is used as a binding agent in the production of long-fiber, lightweight papers (Whistler, 1993; Goldstein and Alter, 1973).

2.6.2. Wood properties of *Sterculia setigera* and their uses

The wood finds some use although it is not a good quality timber. It has been used for making packing cases, match, splints, pencils, picture frames and other miscellaneous items.

CHAPTER THREE

STUDY AREA

3.1. General information of Southern Kordofan State

3.1.1 Location

Southern Kordofan State is located in Central Sudan between latitudes 10° and 13° *N* and longitudes 29° and 33° *E*, in the low rainfall savanna zone in the central clay plains of the Sudan. It covers an area of about 0.14 million square kilometers (Sudan Almanakh, 1967/68). It consists of eight localities (Kadougli, El Dilling, Rashad, Abu Gibaiha, Taloudi, El Muglad, El Salam, and Lagawa).

3.1.2 Main Features

Nuba Mountains series constitute the main topographic feature of the State; the mountain series are divided into east and west series. This study is conducted on the eastern part of the mountain series. The Topography of this area is favorable for the germination and development of gum exudating trees (*Boswellia papyrifera*, *Sterculia setigera*, *Sterculia africana* and *Commiphora africana*).

In the savanna ecological zone of Southern Kordofan, trees stocking densities and their production and yield of NWFPs vary with the site and according to the tree species. These products contribute to the welfare of the local communities (Massaud, 2007).

3.1.3 Population

The Population in Southern Kordofan is estimated at 1.6 millions, according to 1993 census, population growth rate is 3.1%, the population density is 12 persons per Km^2, female households are about 27% in the state. Most of them are Nuba tribes; they are sedentary framers and livestock breeders excluding Camels. Other tribes are nomadic Arabs and Fallata, who usually camp during the rainy season on slightly elevated areas where *Boswellia*, *Sterculia* and *Commiphora,* Forest stands is found. Tribes from other States are also present in the area; these are involved in agricultural activities.

3.1.4 Land tenure and use

Concerning land tenure system in Southern Kordofan, normally the local tribal leaders are responsible for distribution of land for cultivation. The *Sterculia setigera* stands are considered as reserved property of the country and they are under the responsibility of the Forests National Corporation (FNC). Sterculia Gum karaya tappers usually make seasonal contracts with the FNC in collaboration with the local leaders, to avoid conflicts that may arise. However, this system has some defects, as many of the tappers complain that the tribe chiefs charge them much money for giving approval for tapping. This led to intensive tapping to produce more and cover the costs (Elsamani, 1986).

3.1.5 Climate

It is characterized by low temperature, the mean annual temperature is in the range of 24° to 28°C, during winter (20° C in average) and relatively high during summer, where the average temperature is 35° C.

The rainfall in the Southern Kordofan State ranges between 400 mm and over 700 mm per annum fluctuating from year to year (EARS, 1998). The rainy season extends from May to October in Sudan Savanna zone with longer growing season, while it starts late from July in the Southern

Sahel Zone with very short growing season. Rainfall is controlled by the movement of the boundary between dry northerly winds and moist southerly winds (Sudan Almanakh, 1967/68). Table 3.1 shows the mean annual rainfall, temperature and relative humidity in the study area.

Table 3.1 Mean annual rainfall, temperature and relative humidity in Rashad district during the period 1998 – 2007

Month	Mean temperature (°C)	Rainfall (mm)	Relative humidity (%)
January	31	0	25
February	33	0	18
March	35	1.2	11
April	38	5.2	11
May	36	52.8	57
June	33	75.3	62
July	30	126	76
August	29	187.9	83
September	31	140.3	75
October	33	86.6	61
November	33	1.5	28
December	31	0	25
Total		573.4	

Rashad Metrological Station (1998 to 2007 records)

3.1.6 Geology and Soils

The geology of the area is characterized by basement complex formations, which are the oldest and most extensively found in the area. The Nubian sandstone overlies the basement complex in the majority of the area (WSARP, 1982). The area is characterized by many small isolated steep sided hills or small groups of hills which form the Nuba Mountains (Sudan Almanakh, 1967/68). The area is known to have rich mineral deposits such as Copper, Gold, Graphite and Uranium (Elsamani, 1986).

Detritus shallow soils prevail on top and slopes of the hills. However, the plains are dominated by alluvial or clay deposits, mainly along seasonal streams and vallies “Khors or Wadies”. Light and cracking clays, which are reasonably fertile, characterize the traditional production areas (Massaud, 2007).

3.2 Selected locations for the study

The present study was carried out in three different locations the Eastern Nuba Mountains in Rashad locality which lie between latitudes 10° and 13° *N* and longitudes 29° and 33° *E*. Rashad locality occupies a total area of about 7872 km^2; (Sudan Almanakh, 1967/68). Site 1 is ALmazlagan natural forest which is located 20 Km to the North-West of Rashad town. The topography of this site is a series of plateaus covered by a widespread *Sterculia africana* representing the dominant trees in the area associated with few trees of *Boswillia, Combretum* and *Sclerocarya* species.

Site 2 and site 3 are situated in Gabal ALahmer, about 5 Km south-west of Alabassia town in Rashad locality, the area of Gabal ALahmer is one of Nuba mountains series. The natural forest vegetation is mainly *Sterculia setigera* completely covering the area and distributed from the mountain top to the bottom and depressions. Site 2 representing Mountain bottom and site 3 representing Mountain Top).

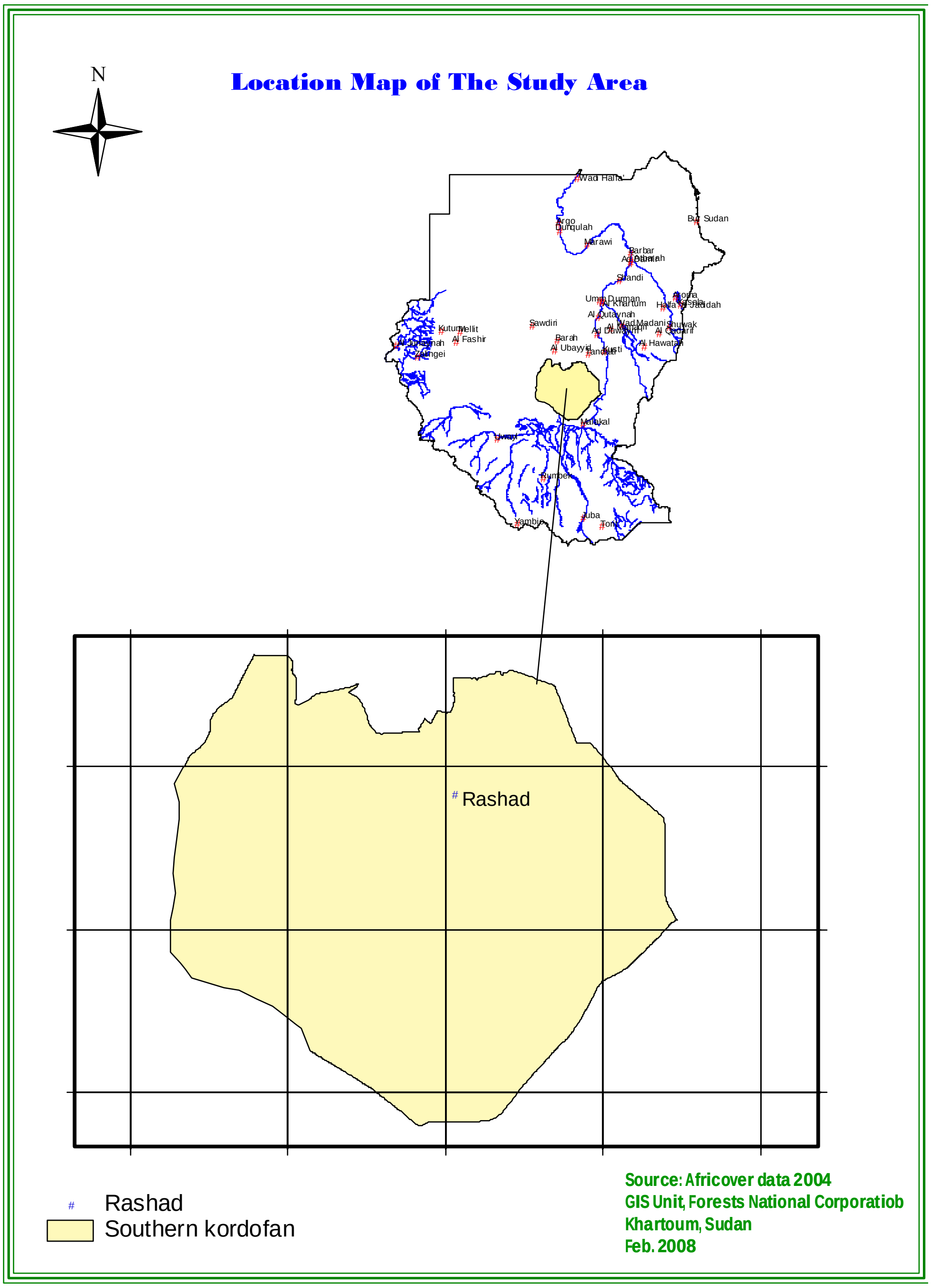

Fig 3.1 map of the Sudan and study area
(Source: FAO- FNC-GIS unit, 2002)

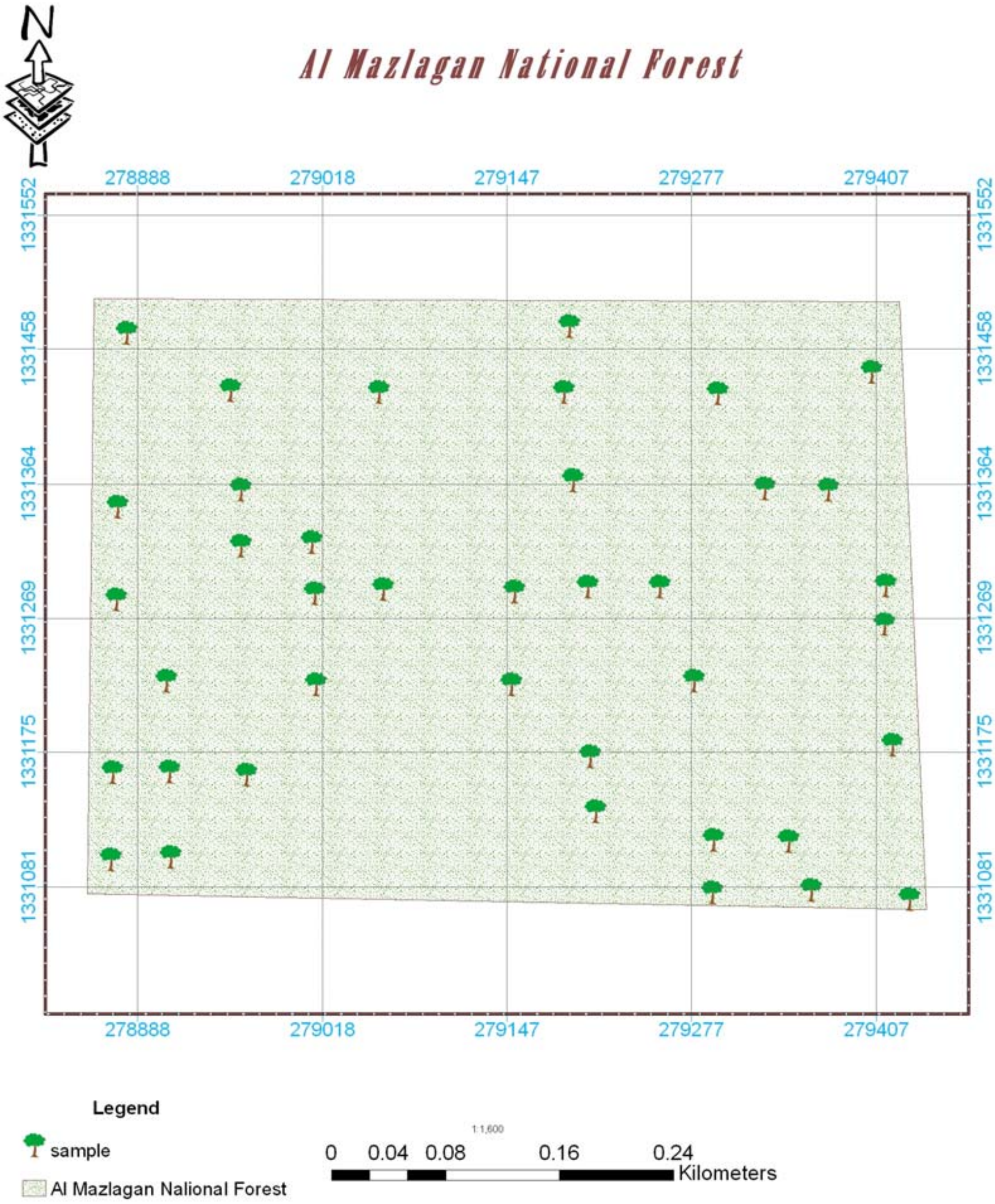

Fig. 3.2 locations of random selected sample plots
(Source: present study, 2006)

CHAPTER FOUR
MATERIAL AND METHODS

4.1 Reconnaissance Survey

A comprehensive survey was made in the Eastern and western mountains of Southern Kordofan State, to be acquainted with areas in which the natural forests of *Sterculia spp*. predominate, and to identify different levels of tree growth, whether the tree is on leveled lands, hills or alongside the mountains, which symbolizes the stretch of Nuba mountains chain. Two areas were selected, in which the beforehand stated facts are existing. These sites include: Almazlagan area at Rashad locality and Gabal Alahamer at Alabassia. Then, Identified areas were fixed and their boundaries were determined by using GPS. The locations of two sites were delineated with registration of their exact coordinates. Furthermore, ground survey around them was conducted with the help of a key-person from the area. In addition to the information collected on practice and techniques of tree tapping, gum collection and storage.

4.2 Experiment lay-out

The total area for this study is 75 hectare representing three locations: site I covers a squared area of 25 haectare (500 m x 500 m). Site 2 and site 3 each covering 25 hectare also. In three sites, 50 circular sample plots were laid out. The area of the sample plot is 0.1 ha, making a total of 15 hectare sampled area (five hectare in each site). The sampling percent used is therefore equal to 20%. Fifty sample plots were randomly chosen in the three selected site by using randomized tables, the range is restricted from 1 to 250 (1.0 ha represents 5 ha, each ha=10 s.p) the sample plots were distributed from South to North in the map.

Furthermore the distance on the basic map was determined for each sample plot and the following one and the angle was measured by using protractor. Thereafter the designed sampling plan was implemented in the field.

4.3 Field work

According to the information delineated from the map for each sample plot, samples were listed from the South to the North starting with the first sample plot by using GPS. The coordinates of each sample plot were recorded in the GPS. Circular sample plots with a radius of 17.84 m (0.1 hectare in area) were used. In each of the sample plots the number trees was counted and recorded. Thereafter, the closest three trees to the centre of each sample plot were marked and selected for tapping, Certain tree growth parameters were measured, namely diameter at breast height (dbh) using caliper or diameter tape, tree height (h) using a Haga, tree bole height (bh) and crown height (ch) by using Haga or a distantance tape. moreover, the major observations in each sample plot was registered that indeed: natural regeneration and pests which attack the *Sterculia`s* seeds.

Determination of the sample plots position and the centre of the first sample plot and second sample plot was done by using GPS. This procedure was followed until the 50 sample plots have been covered. A total of 392 trees were selected in selected locations for tapping as follows; 116 trees from ALmazlagan area, 141 and 135 trees from bottom and top of Gabal Alahmer Mountains respectively (some sample plots were empty or occupied by species other than *Sterculia*).

4.4 Data collection

4.4.1 Method of tapping

Based on local knowledge experiences and traditional practice at the beginning of October 2006 all selected trees were tapped in the study area by using an axe, where 6 blazes per tree were made, dimensions of a blaze were 5 cm length x 5 cm width x 2 cm depth. The direction of tapping was North-South or East-West. 3 blazes on the southern side and 3 blazes on the northern side of the tree were made.

4.4.2 Gum collection

The first gum picking was collected after one month from the first tapping. Gum was collected from each tree and deposited in polythene bag on which tree number and location were recorded. The gum quantity of each picking was weighed by using a sensitive balance (Adam portable balance). After the first gum collection, re-tapping (gum picking and re-tapping simultaneously were done on the tree which removal 2 cm above from the first blaze on the back of the trees) was made on each tree for the second collection. The interval between the first and second collection was two weeks. Thereafter, tapping and gum collection was performed twice a month, with the exception of the first month where the tapping and gum collection was done only once. The practice of tapping and gum collection continued from October 2006 to the end of May 2007.

4.4.3 Statistical analysis

Relying on the local experience knowledge, Gum was picking from the study area on monthly basis, starting from October 2006 to May 2007 from the three locations. The data was grouped by site after being classified into strata**.** Then**,** recorded in spread forms and has been entered in spread sheet of Excel, which include: tree diameter at breast height (dbh), tree height (h), bole height (bh), crown height (ch) and gum picking per month per tree (y), in all locations of the study area. Data were submitted to ANOV using the statistical soft ware SAS program. The relationships among growth parameters and gum production were listed with correlation and regression analysis. Furthermore, JMP program a package from SAS was also used to investigate the effect of growth parameters on gum production and correlation between growth parameters in the different three locations.

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1. Relationships between site and measurable growth parameters

The analysis of variance indicates that, there was no significant variation between measurable growth parameters in different sites.

The relationships between measurable growth parameters DBH, H and CH across the range of different sites covered by *Sterculia spp.* are shown by the results of regression analysis given in tables 5-1 to 5-3.

The results show that there is significant correlation between measurable growth parameters at $p \leq 0.05$ in the three locations. Strong relationship was found between crown height and tree height in mountain top site where (r^2=0.94, P=.0001), and weaker relationship was found between crown height and diameter at breast height in plateau site (r^2=0.70, P=.002).

5.1.1. High altitude (Mountain Top)

Relationships between tree diameter, tree height and crown height were investigated on high altitudes, where tartar trees are growing.

The statistical analysis in table 5.1 shows the results of these relationships.

Table 5-1 Relationship between H, CH and DBH on high altitude.

Equation No	Equation	r^2	*P*
5-1	H = 6.81520+0.06463*DBH	0.90	.0001
5-2	CH = 2.18335+0.07866*DBH	0.89	.0001
5-3	CH = -5.79904+ 1.19000*H	0.94	.0001

Equations 5-1 and 5-2 indicate a strong relationship between diameter at breast height and tree height and crown height (r^2=0.9 and .089 at P<0.0001). this is coincide with (Cris Brack, 1999) reported that, there is a strong linear relationship between crown height and diameter at breast height.

Equation 5-3 shows that there is a strong relationship between crown height and tree height (r^2=0.94 at P<0.0001).

5.1.2. Low altitude (Mountain bottom)

Relationships between tree diameter, tree height and crown height were investigated on low altitudes, where tartar trees are growing

The statistical analysis in table 5.2 shows the results of these relationships.

Table 5-2 show Relationship between H, CH and DBH on lower altitude

Equation No	Equation	r^2	*P*
5-4	H = 8.37772+0.04703*DBH	0.0.73	.0004
5-5	CH = 4.52467+0.05209*DBH	0.80	.0001
5-6	CH = -3.00820+ 0.95976*H	0.83	.0001

Equations 5-4 and 5-5 indicate that there is a strong relationship between diameter at breast height, tree height and crown height r^2=0.73 and 0.80 at significance levels P<.0004 and .0001 respectively. The result agree with (Cris Brack, 1999) reported that, there is a strong linear relationship between crown height and diameter at breast height.

Equation 5-6 indicates that there was a strong relationship between average crown height and average height (r^2=0.83 at P=.0001)**.**

5.1.3. Plateau (depressed area)

Relationships between tree diameter, tree height and crown height were investigated on plateau site, where tartar trees are growing.

Table 5-3 shows the correlation relationships between H, CH and DBH at the plateau.

Table 5-3 Relationship between H, CH and DBH on plateau.

Equation No	Equation	r^2	*P*
5-7	H = 4.94254+0.08463*DBH	0.93	.0001
5-8	CH = 1.66464+0.06789*DBH	0.70	.002
5-9	CH = -2.53873+ 0.82333*H	0.78	.0007

Equations 5-7 and 5-8 indicate that there is a strong relationship between diameter at breast height average height and crown height (r^2=0.93 and 0.70 at significance levels P<.0001 and .002) respectively. The result is going on line with (Cris Brack, 1999) reported that, there is a strong linear relationship between crown height and diameter at breast height.

Equation 5-9 indicates that there was a strong relationship between average crown height and average height (r^2=0.78 at P=.0007).

5-2 Relationship between monthly gum picking and diameter at breast height on high altitude (Mountain Top)

Equations in table 5-4 display the variation of correclation relationship between gum picking and diameter at breast height by month.

Table 5-4. Relationship between gum picking and diameter at breast height by month.

Equation No	Month	Equation	r^2	P
5-10	October	Y1 = zero	-	-
5-11	November	Y2 = 963.58762 - 8.40926*DBH	0.58	0.004
5-12	December	Y3 = 1653.32400 - 14.73103*DBH	0.79	0.0001
5-13	January	Y4 = 1203.04619 - 10.76530*DBH	0.82	0001
5-14	February	Y5 = 445.23688 - 3.84773*DBH	0.70	0.0008
5-15	March	Y6 = 1372.06292 - 12.01889*DBH	0.73	0.0004
5-16	April	Y7 = 2205.72857 - 19.38776*DBH	0.70	0.0007
5-17	May	Y8 = 1311.76731 - 11.50822*DBH	0.74	0.0003

Equations 5-11 to 5-17 indicate that there are significant variations at ($P \leq 0.05$) in the monthly gum picking related to diameter at breast height. Strong linear relationship is found in equation 5-13 where (r^2 0.82, P<.0001).

The relationship between total gum production for all months and diameter at breast height is given in table 5-5.

Table 5-5 Relationship between total gum production and diameter at breast height.

Equation No	Equation	r^2	*P*
5-18	TY = 9154.75348 + -80.66819*DBH	0.74	.0003

From equation 5-18 illustrated in table 5-5 it is obvious that there is a strong correlation relationship between total gum production and diameter at breast height, where ($r=^2$ 0.74, P= .0003).

5.3. Relationship between monthly gum picking and diameter at breast height on low altitude (Mountain bottom)

Table 5-6 shows the relationship between monthly gum picking and diameter at breast height.

Table 5-6 Relationship between gum picking and diameter at breast height by month

Equation No	Month	Equation	r^2	*P*
5-19	October	Y1 = zero	-	-
5-20	November	Y2 = 627.67178 + -3.93149*DBH	0.28	0.07
5-21	December	Y3 = 1354.43077 + -11.61955*DBH	0.53	0.007
5-22	January	Y4 = 788.56147 + -6.98694*DBH	0.56	0.004
5-23	February	Y5 = 589.60469 + -4.94997*DBH	0.50	0.01
5-24	March	Y6 = 740.71531 + -6.23466*DBH	0.52	0.007
5-25	April	Y7 = 1844.38081 + -15.93570*DBH	0.62	0.002
5-26	May	Y8 = 1480.37254 + -12.76541*DBH	0.55	0.006

Equations from 5-20 to 5-26 indicate that there is a strong correlation relationship between diameter at breast height at (*P*= 0.007, 0.004, 0.01, 0.007, 0.002, 0.005) and monthly gum picking, where r^2 was 0.53, 0.56, 0.50, 0.52, 0.62, 0.55 respectively.

Equation 5-20 show that the relationship is not significant (*P*= 0.07).

On low altitude the relationship between total gum production (gm) and diameter at breast height (cm) is shown in table 5-7.

Table 5-7 Relationship between total gum production and diameter at breast height.

Equation No	Equation	r^2	*P*
5-27	TY = 7425.73736 + -62.42372*DBH	0.55	0.006

The results of the regression analysis revealed that a significant proportion of the variation in the total gum collection was related to diameter at breast height (r^2 0.55, *P*=0.006). The same results were found in stepwise analysis as diameter at breast height was squared and inserted (for the same probability level: $P \leq 0.05$)

5.4. Relationship between monthly gum picking and diameter at breast height on Plateau (depressed area)

In this site the results show that there was no significant correlation relationship between monthly gum picking and diameter at breast height. Similar results were found for the total gum production at the same probability level ($P \leq 0.05$).

5.5. Relationship between monthly gum picking and crown height on high altitude (Mountain Top)

Tables 5-8 to 5-13 show the gum picking of *Sterculia setigera* in relation to tree crown height.

The results show that there is strong relationship between gum picking in high and low altitudes related to tree crown height at $p \leq 0.05$. While in plateau site the results show a weaker relationship at (P=0.05) except in December and March.

Table 5-8 Relationship between gum picking and crown height by month.

Equation No	month	Equation	r^2	*P*
5-29	October	Y1 = zero	-	-
5-30	November	Y2 = 1013.96753 + -83.80087*CH	0.40	0.02
5-31	December	Y3 = 1816.87282 + -156.30416*CH	0.62	0.002
5-32	January	Y4 = 1309.96218 + -112.63461*CH	0.62	0.006
5-33	February	Y5 = 484.91548 + -40.44273*CH	0.53	0.005
5-34	March	Y6 = 1481.90322 + -124.54806*CH	0.55	0.005
5-35	April	Y7 = 2387.50811 + -201.48956*CH	0.53	0.007
5-36	May	Y8 = 1433.69721 + -121.37141*CH	0.58	0.004

The equations in table 5-8 show the gum picking of *Sterculia setigera,* by month in relation to tree crown height. There is fair relationship ($p \leq 0.05$) as r^2 ranges between 0.40 and 0.62.

Equation 5.37 in table 5-9 shows the relationship between total gum production and tree average crown height on mountain top.

Table 5-9 Relationship between total gum production and crown height

Equation No	Equation	r^2	*P*
5-37	TY = 9928.82654 + -840.59140*CH	0.56	0.004

It is obvious that there is fair relationship between total gum production and crown height (r^2=0.56 at P=0.004).

5-6. Relationship between monthly gum picking and crown height on lower altitude (Mountain bottom)

The relationship between gum picking by month and tree crown height on mountain bottom is shown in Table 5-10.

Table 5-10 Relationship between gum picking and crown height by month

Equation No	month	Equation	r^2	*P*
5-38	October	Y1 = zero	-	-
5-39	November	Y2 = 939.38096 + -71.89361*CH	0.32	0.05
5-40	December	Y3 = 1969.98551 + -175.76102*CH	0.41	0.02
5-41	January	Y4 = 1199.40257 + -110.57588*CH	0.48	0.01
5-42	February	Y5 = 820.92839 + -71.16257*CH	0.35	0.04
5-43	March	Y6 = 1087.61124 + -96.30265*CH	0.42	0.02
5-44	April	Y7 = 2814.01584 + -256.11502*CH	0.54	0.006
5-45	May	Y8 = 2189.33519 + -197.02225*CH	0.44	0.02

The equations in table 5-10 show that there is weak relationship between monthly gum picking and crown height at $P \leq 0.05$.

Equation 5.46 in table 5-11 shows the relationship between total gum production (gm) and crown height (m) on mountain bottom.

Table 5-11 Relationship between total gum production and crown height

Equation No	Equation	r^2	*P*
5-46	TY = 11021 + -978.83300*CH	0.45	0.01

It is obvious that there is weak relationship between total gum production and crown height (r^2=0.45 at P=0.01).

5.7. Relationship between monthly gum picking and crown height on plateau (depressed area)

The equations in table 5-12 show the relationship between monthly gum picking and crown height.

Table 5-12 Relationship between gum picking and crown height by month

Equation No	Month	Equation	r^2	*P*
5-47	October	Y1 = 393.81375 + -45.59580*CH	0.27	0.1
5-48	November	Y2 = 676.6605 + -67.36601*CH	0.33	0.08
5-49	December	Y3 = 635.51449 + -69.16132*CH	0.41	0.04
5-50	January	Y4 = 479.88278 + -50.41713*CH	0.34	0.07
5-51	February	Y5 = 315.73700 + -33.65184*CH	0.37	0.06
5-52	March	Y6 = 304.49045 + -27.66729*CH	0.40	0.05
5-53	April	Y7 = 526.41587 + -45.91744*CH	0.28	0.1
5-54	May	Y8 = 314.18095 + -26.61896*CH	0.22	0.1

The equations in table 5-12 show that there is weak relationship between monthly gum picking and average crown height at $P \leq 0.05$.

Relationship between total gum production and crown height at the plateau site is shown in table 5-13.

Table 5-13 Relationship between total gum production and crown height

Equation No	Equation	r^2	*P*
5-55	TY = 3646.69580 + -366.30579*CH	0.43	0.04

It is clear that there is a weak relationship between total gum production related to crown height ($r^2 = 0.43$ at $P \leq 0.05$).

5.8. Relationship between monthly gum picking and tree height on high altitude (Mountain Top)

Table 5-14 shows the relationship between monthly gum picking and tree height.

Table 5-14 Relationship between gum picking and tree height by month

Equation No	month	Equation	r^2	*P*
5-56	October	Y1 = zero	-	-
5-57	November	Y2 = 1514.09754 + -100.95165*H	0.39	0.03
5-58	December	Y3 = 2823.79192 + -194.71887*H	0.64	0.001
5-59	January	Y4 = 2041.33101 + -140.81723*H	0.65	0.001
5-60	February	Y5 = 715.61442 + -47.79469*H	0.50	0.01
5-61	March	Y6 = 2271.88078 + -154.08550*H	0.56	0.005
5-62	April	Y7 = 3651.59037 + -248.06725*H	0.53	0.007
5-63	May	Y8 = 2207.49687 + -150.49987*H	0.59	0.003

Equations in table 5-14 show that there is fair relationship between the gum picking of *Sterculia setigera,* by month and tree average height ($p \leq 0.05$) in all months, as the correlation coefficient between gum picking and tree average height ranges between 0.39 in November and 0.65 in January.

The equation in table 5-15 shows the relationship between total gum production and tree height.

Table 5-15 Relationship between total gum production and tree height

Equation No	Equation	r^2	*P*
5-64	TY = 15226 + -1036.93506*H	0.57	0.004

The results ($r^2=0.57$ at $P \leq 0.05$) is almost like average of all collection months related to tree height at ($P \leq 0.05$).

5.9. Relationship between monthly gum picking and tree height on low altitude (Mountain bottom)

The relationship between gum picking by month and tree height is shown in table 5-16.

Table 5-16 Relationship between gum picking and tree height by month

Equation No	month	Equation	r^2	*P*
5-65	October	Y1 = zero	-	-
5-66	November	Y2 = 1137.13 - 67.43242*H	0.25	0.09
5-67	December	Y3 = 2736.76904 - 188.84918*H	0.42	0.02
5-68	January	Y4 = 1657.85989 - 116.78207*H	0.48	0.01
5-69	February	Y5 = 1128.97024 - 76.25718*H	0.36	0.03
5-70	March	Y6 = 1532.51762 - 105.757171*H	0.45	0.01
5-71	April	Y7 = 3767.2412 - 261.28630*H	0.51	0.009
5-72	May	Y8 = 2965.46832 - 204.63034*H	0.43	0.02

The results revealed from table 5-16 show that there is significant difference in monthly gum picking related to tree height at ($P \leq 0.05$) except in November.

Equation 5-73 in table 5-17 shows the relationship between total gum production and tree height.

Table 5-17 Relationship between total gum production and tree height

Equation No	Equation	r^2	*P*
5-73	TY = 14926 -1020.80921*H	0.44	0.01

The results show that there is significant difference in total gum production related to tree height at ($P \leq 0.05$).

5.10. Relationship between monthly gum picking and tree height on plateau (depressed area)

The results of variance analysis in this site showed that there was no significant variation between monthly gum picking and total gum production related to tree height at the same probability level ($P \leq 0.05$).

The analysis of correlations between different measurable growth parameters and monthly gum picking and total gum production. Strong relationship were found between picking Y4 (January) and diameter at breast height on mountain top (r^2= 0.82 and P= .0001) and the weaker relationship between picking Y8 (May) and crown height on plateau site where (r^2= 0.22 and P= 0.1).

5.11 Additivity

The addition of equations, fitted to different gum pickings collected monthly from the same species growing in different locations, resulted in constant and coefficient values compatible with those obtained from fitting the total gum production composed of the those monthly pickings components. The equations obtained are exactly identical. Table 5.18 indicates that the addition of the constants and coefficient of gum yield components by diameter at breast height, crown height and height classes for the same species resulted in constant and coefficient values identical to those obtained from the total gum production for same classes.

Table 5.18 Equations for total gum production and addition components.

location	Equation of Addition components	Equation of Total component
Top	TY = 9154.6 + -80.6*DBH	TY = 9154.75348 + -80.66819*DBH
Bottom	TY = 7425.8 + -62.5*DBH	TY = 7425.73736 + -62.42372*DBH
Top	TY = 9929.1 + -840.5*CH	TY = 9928.82654 + -840.59140*CH
Bottom	TY = 11020.7 + -978.9*CH	TY = 11021 + -978.83300*CH
plateau	TY = 3646.7 + -366.4*CH	TY = 3646.69580 + -366.30579*CH
Top	TY = 15225.7 + -1037*H	TY = 15226 + -1036.93506*H
Bottom	TY = 14925.9 + -1020.8*H	TY = 14926 -1020.80921*H

5.12.1 Effect of site on gum production

The result of analysis of variance for the total gum production by three sites is given in table 5.19.

Table 5.19 the effect of the three sites on total gum production

site	Mean*
	Total gum
1	**96.9 B**
2	**272.3 A**
3	**279.9 A**
Significance level	**P<0.0001**
Standard error	**17.8**

*means with the same letter are not significantly different

site 1 = plateau   site 2 = mountain bottom   site 3 = mountain top

Significant (P< 0.0001) variation was found between site 1 and the other two sites. No significant differences were found in the total gum production in site 2 and site 3, and hence they have given significantly higher gum production of the sites.

The analysis of variance indicates that, there was no significant variation between measurable growth parameters in different sites. It seems that the site has significant and major effect on total gum production. This finding is supported by other researchers.

Figure 5.1 display the variability in gum production according to sites. The higher gum yield was found on the mountain top during April. The present study shows that hottest months of the year (March, April and May) yielded the best gum quantity and quality, and hence they are the best months for gum production. This agrees with (Howes, 1949), (Goldstein and Alter, 1973), (Coppen, 1995) and (FAO, 1995) who reported that the best quantity and quality of gum is collected during April and May. Gum yield was high in December because the temperature increased sharply during this period of tree tapping. The plateau is covered mainly by *Sterculia africana,* which showed the lowest productivity during the whole months compared to *Sterculia setigera*.

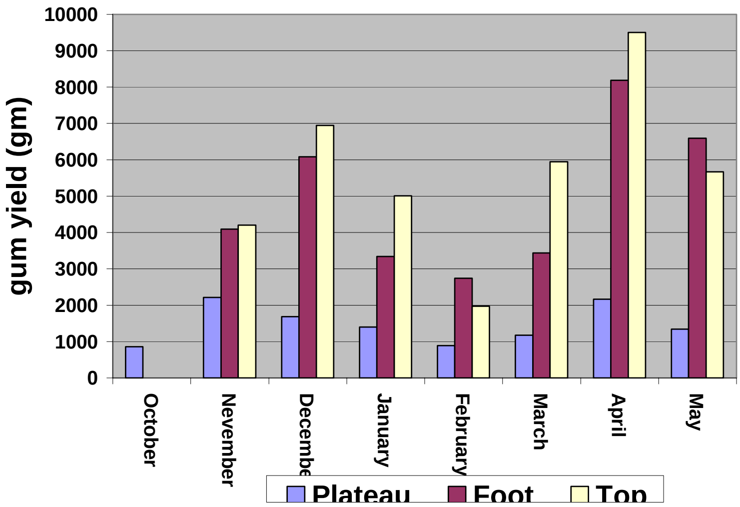

Fig.5.1. Monthly gum picking from October 2006 to May 2007 by sites

5.12.2 Effect of tree size on gum production

In the present study it was found that gum picking per-tree was strongly affected by tree diameter. A high dependency of gum production per tree on tree diameter was observed; somewhat surprisingly, the highest production was obtained from diameters ranging between 40-60 cm, followed by the smaller diameter sizes (d> 40 cm), and the lowest gum production was obtained from trees representing the largest diameter sizes (d<60 cm). This result is in line with the findings of (Abdel Rahman 2001, Ballal 2002, Gaafar 2005). Who found that there is a significant effect of *Acacia senegal* tree size on gum production.

5.12.3 The effect of monthly gum picking on total gum production

Regression modeling was performed to investigate the relationship between monthly gum production and total gum production (table 5.20).

Table 5.20 shows the effect of monthly gum picking on total gum production.

Equation No	Equation	r^2	*P*
5-74	TY = 22.75 – 0.729 * Y1	0.002	0.78
5-75	TY = 141.4 + 2.5 * Y2	0.39	.0001
5-76	TY = 61.6 + 4.3 * Y3	0.66	.0001
5-77	TY = 80.6 + 5.9 * Y4	0.47	.0001
5-78	TY = 106.7 + 8.2 * Y5	0.56	.0001
5-79	TY = 102.4 + 4.25 * Y6	0.54	.0001
5-80	TY = 45.33 + 3.6 * Y7	0.68	.0001
5-81	TY = 54.6 + 4.9 * Y8	0.65	.0001

The present study shows that, 67% and 65% of the variation in gum picking can be explained by the variation in gum production in Y7 and Y8 respectively total gum production, and both can be used as indicators for the total gum production.

5.12.4 The effect of measurable growth parameters on total gum production

Figures 5.2 to 5.4 shows the effect of measurable growth parameters on total gum production in the three locations

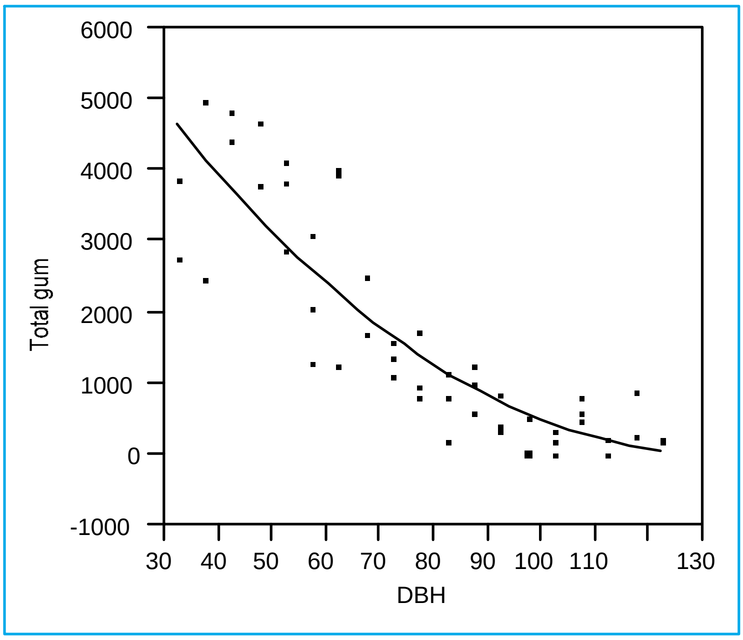

Fig. 5.2 Relationship between DBH and total gum production

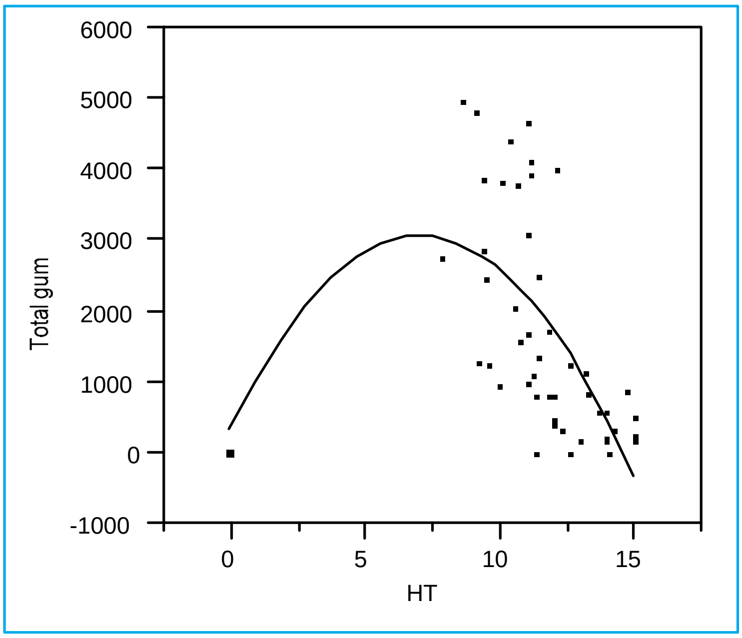

Fig. 5.3. Relationship between height and total gum production

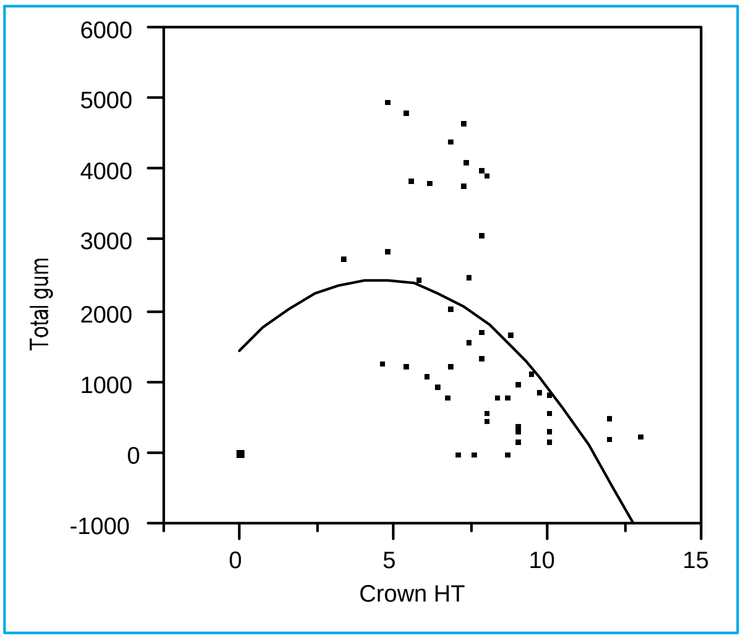

Fig.5.4 Relationship between crown height and total gum production

The analysis of variance in table 5.21 shows a statistically significant ($P=0.01$) effect of diameter at breast height on total gum production. Table 5.22 shows the relationship between measurable parameters and total gum production for the three locations.

Table 5.21. Effect of measurable growth parameters on total gum production in the three locations.

Equation No	Equation	r^2	*P*
5-82	TY = 8140.67 – 122.879 DBH + 0.46455 DBH^2	0.76	<.0001
5-83	TY = 352.572 + 767.176 H – 54.1016 H_2	0.42	<.0001
5-84	TY = 1443.75 + 450.726 CH – 49.8788 C H^2	0.27	0.0006

Concerning the variation between different measurable growth parameters and total gum production, diameter at breast height seems to have the strongest relationship with total gum production, hence it can be considered as the best indicator for gum production in the area. This result is in contrast with (Hineit, 2007), who reported that, the relationship between gum production and tree diameter was not significant within the tree size-classes of Gum Talha.

The results show that there is always a strong relationship between the measurable tree parameters and gum production. The relationships between tree parameters and gum production are weakest in the plateau. The results also show that *S. africana* has very low productivity in gum. This finding coincides with what is mentioned in the literature (Coppen, 1995 and Verma, 1988), who described, *S. africana* as being a tree of low or no gum production.

On the three selected locations for the study it was observed that there is absolutely no natural regeneration on mountain bottom and depressed areas, very scarce regeneration was found scattered on mountain top (1-2 seedling in random sample plot with radius equal to 2 m). This phenomenon is an indication that, *Sterculia Spp*. is at risk and might disappear altogether if nothing is made to ensure its regeneration

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The following conclusions could be drawn from this study

- Total gum production was strongly effected by different locations.
- The high gum production was found in mountain top, mountain bottom and plateau respectively.
- Highest production from diameters ranging between 40-60 cm followed by the smaller diameter sizes (d> 40 cm) and the lowest gum production from largest diameter sizes (d<60 cm).
- There was no significant variation between the measurable growth parameters across the different locations.
- Diameter at breast height was strongly effect in total gum production and it can consider as the best indicator for gum production in the area.
- Gum production increased towards the hottest months of the year (March, April and May) yielded the best gum quantity and quality.
- Gum production per-tree was strongly affected by tree diameter size
- The effects of monthly gum picking on total gum production were recognized.
- Tapping may be considerably increase gum tartar production in Rashad locality and Southern Kordofan State.

6.2 Recommendations

- Tartar gum tappers must be trained to practice good tapping and harvesting techniques of *Sterculia spp*. trees.
- Further research is required to investigate the response of *Sterculia africana* trees growing in natural forests to other methods of tapping in different climatic conditions.
- Research is required to investigate the effect of intensity of tapping on gum production relying on the number of blazes on the tree.
- Tree improvement is recommended so as to guarantee more gum production of *Sterculia* trees.
- Tapping on mountain top were recommended.
- Tapping of *Sterculia africana*, were not recommended.
- A sustainable management plan should be designed to ensure good management of *Sterculia spp* stands to meet the urgent needs of productive and protective purposes.

References

Abdel Rahman, H. M. (2001). Effect of some growth parameters and age on gum and seed yield of A. senegal plantations and natural stands in North Kordofan. MSc.,Faculty of Forestry, University of Khartoum.

Allen, H. E. and McCaleb, A. G. (1938). A method or process of manufacturing sausages and sausage-felling composition. GB patent application 483-925.

Anderson, D. M. W. (1988). The chemical characterization of some Astragalus gum exudates. Food Hydrocolloids 2:417-423.

Anderson, D. M. W., (1993). Some factors influencing the demand for gum arabic (Acacia senegal (L.willd) and other water-soluble tree exudates. Forest Ecology and Management 58, 1-18.

Anderson, D. M. W.; McNab, C. G. A.; Anderson C. G.; Brown, P. M. and Pringuer, M. A. (1982). Studies of uronic acid materials, part 58*; gum exudates from the genus Sterculia (gum karaya). International tree crop journal, 2 , 147-154

Andrews, F. W. (1952). The flowering plants of Anglo-Egyptian Sudan (vol. 1). T. Buncle and Co. LTD Arbroath, Scotland.

ANON. (1987). Market Survey for Select Minor Forest Products in France, UK, USA and Japan. 157 pp. New Delhi: Indian Institute of Foreign Trade.

Ballal, M. E. (2002).Yield trends of gum Arabic from Acacia senegal as related to some environmental and managerial factors. PhD thesis. University of Khartoum.105 p.

Bashir. A. E. and Jens. G. (2004). Non-timber Forest Products: opportunities and constraints for Poverty Reduction in the Nuba Mountains, South Kordofan, Sudan. Paper presented in a Conference on International Agricultural Research For Development, Berlin (2004).

Beach, P. L. (1969). Preparation of a proteincaceous food salad. US patent application 3,454,405.

BIS (1988). Specification for gum karaya, grade. Indian Standard IS: 12408?1988. 6 pp. New Delhi: Bureau of Indian Standards.

Boiteau, C. and Blondeel, G. (1981) Tampon having a surface covering. GB patent application 2,075,846.

Carpenters, (1979) Seals for colostomy or like bags. GB patent application 2,017,501.

Chopra, R. N., Chopra, L. C. and Nayar, S. L. (1956). Glossary of Indian medicinal plants. Council of Scientific and Industrial Research. New Dehli.330 p.

Coppen, J. J. W. (1995). Gums, resins and latexes of plant origin. FAO Technical Papers, Non-wood forest products – 6, FAO, Rome.

Cris, H. F. and Brack, C. L. (1999). Stand volume estimates from modeling inventory data. *Australian forestry* 4:360- 367.

Debeer, J. H. and McDermott, M. M. (1989). The economic value of NTFPs in southeastern Asia. The Netherland Committee for IUCN. Amesterdam.

Dovie, D. B. K. (2003). Rural economy and livelihoods from the non-timber forest products trade. Compromising sustainability in southern Africa? International Journal of Sustainable Development and World Economy.

Dziezak, J. D. (1991). A focus on gums. Food Technol 45:116-132.

EARS. (1998). Diagnostic survey report. Assignment report of multi-disciplinary team from El Obeid Agriculture Research Station (EARS), prepared for the Ministry of Agriculture and Forestry South and West Kordofan, Agricultural Development Project(SWKADP).

Sanjak. A. M. (2000). The Contribution of Non Timber Forest Products to Local Livelihood in Southern Kordofan State, Sudan.

El Amin, H. M. (1973). Sudan Acacias.Forest Research Institute Bulletin No. 1, Khartoum.

El Amin, H. M. (1990). Trees and shrubs of the Sudan. Ithaca press.

ELsamani, (1986). Kordofan rehabilitation development strategy, No. 1 main report. Ministry of Finance and Economic Planning and UNDP, Khartoum, Sudan.

FAO, (1991). Non-wood forest products: the way ahead. FAO Forestry Paper NO. 97, FAO, Rome.

FAO, (1995). Report of the international expert consultation on non-wood forest products. FAO Technical Papers, Non-wood forest products – 3, FAO, Rome.

FAO/FNC. (1998): Natural forest inventory, Kordofan region, Khartoum, Sudan.

FAO, (2002). Multipurpose Africover Databases on Environmental resources (MADE) available for 10 countries.

Gaafar, A.M. (2005). Improvement of Acacia senegal agroforestry: Ecophysiological characteristics as indicators for tree-crop interaction on sandy soil in western Sudan. Doctoral thesis. Univ. Helsinki Tropical Forestry Rep. 26. 100 p.

Gaafar, A. M. and Bulgies, M. O. (1997). Increasing pressure on woody forest products, Sudan case study, Stockholm, Sweden.

Goldstein, A.M. and Alter, E.N. (1973). Gum karaya. In Industrial gums: polysaccharides and their derivatives (second edition). Whistler, R. L. and Miller, J. N. (eds.). Academic Press, New York.

Hieneit. B. M. (2007). Effect of Type, Time of Tapping and Tree Size of Acacia seyal var. seyal on the Production of Gum Talha In Rawasha Forest, Gedarif State, Sudan. MSc. thesis submitted to Khartoum Unisersity.

Howes, F. N. (1949). Vegetable gums and resins. The Chronica Botanica Co. U.S.A.

Imeson, A. (1992). Exudates gums. In: Imeson. A. (ed) Thickening and gelling agents for food. Chapman and Hall, London, pp 66-97.

Kelly, B. j. and Potter. N. N. (1990). Dialyzable calcium from milk processed with soluble fiber-containing gums, thickeners, and cocoa. J Food Sci 55:1004-1007.

Kumar, N. and N, C. Saxena. (2002). Indian forests: potential for poverty alleviation. Pages 99-136 in U. J. Leele, editor. Managing a global resource: challenges of forest conservation and development. Transaction Publishers, New Burnswisk, New Jersey, USA.

Malhotra, K. C. Deb, D. Dutta, M. Vasula, T.S. Yadav, G. & Adhikari, M. (991) Role of non-timber forest produce in village economy. A household survey in Jamboni Range, Midnapore, West Bengal. Calcutta, India, Indian Institute of Biosocial Research and Development (IBRAD).

Marsan, A. E. (1967). Sealing pad for a post-surgical drainage pouch. US patent application 3,302,647.

Massaud, M. M. (2007). Regeneration and Propagation of *Sclerocarya birrea* (A. Rich.) Hochst. Tree in Rashad Area at Nuba Mountains, Southern Kordofan State. MSc. thesis submitted to Khartoum Unisersity.

Maydell, H. T. (1990). Trees and shrubs of the Sahel: Their characteristics and uses. Verlag Josef Margrof, GTZ.

Meer, W. (1980). Gum karaya. In Handbook of water-soluble gums and resins. Davidson, R. C., (ed.). Mc Grow-Hills, New York.

Nair, M. N. B.; Shivanna, K. R. and Mohan Ram, H.Y. (1995). Ethephon enhances karaya gum yield and wound healing respone: a preliminary report. Curr Sci 69:809-810.

Partyka, A. (1963). Salsd dressing. GB patent application 936,531.

Robbins, S. R. J. (1988). A review of recent trends in selected markets for Water-Soluble gums. UK overseas development natural resource, Institute Bulletin No. 2. V I, 108 pp.

Ross, J. H. (1979). In A conspectus of the African Acacia species, memoirs- botanical survey South Africa. Kilick, D. J. B. (ed.). Republic of South Africa, No. 44.pp 1-151.

Sanderson, G. R. (1996). Gums and their use in food systems. Food Technol 50:81-84.

Steinhardt, A. and Goldwater. F. A. (1962). Gelatin adhesive pharmaceutical preparations. US patent application 3,029,187.

Sudan Almanakh, (1967/68). Information magazine. The Central Office of information. The republic of the Sudan, Government Printing Press, Khartoum, Sudan.

Thirakul, S. (1984). Manual of dendrology. Group Poulin, Theriault Ltee Consultants. Quebec, Canada.

Verbeken, D. S. (2003). Exudate gum: occurrence, production and applications. Applied Microbiology and Biotechnology, Vol. 63(1), pages 10-21.

Verma, V. P. S. (1988). Experimental tapping of *Sterculia villosa* Roxb. For gum karaya. Indian Forester, 103(4), 269-272.

Weerawardane, N. D. R. (2003). Paper was prepared based on "Challenges and Opportunities in Forestry for the New Millennium.

Weiping, W. (2000). Tragacanth and karaya. In: Philips GO, Williams PA (eds) Handbook of hydrocolloids. Woodhead, Cambridge, pp 155-168.

Whistler, R. L. (1993). Exudate gums. In: Whistler. R. L. and Bemiller. J. N. (eds) Industrial gums: polysaccharides and their derivatives. Academic Press, San Diego, pp 318-337.

World Bank (2002). Global economic prospects and the developing countries 2002: making trade work for the world's poor. The World Bank, Washington, D. C. 253 p.

WSARP, (1982). Work plan Volume 111. Research plan for Kadogli and other stations, WSARP publications No. 15, Khartoum, Sudan and Pullman,

Washington, USA.